Subject: Evaluation of EMI with the Wiener Power Supply Prototype

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From: Craig Drennan

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I. Introduction

This memo reports the findings of our electro-magnetic interference test performed on the candidate power supply for the Minos Far Detector. The conclusions and recommendations are presented first. Description of the tests performed and various spectrum analyzer screen shots with brief explanations are included.

The unit under test is a Wiener Plien & Baus VME/VXI UEP6021 series power supply. This power supply was determined to be the best candidate for a low noise switching supply because it was specified to meet the FCC class B criteria for radiated and conducted noise, and specified a VDC output ripple of less than 15 mV peak-peak.

II. Evaluations and Results

The following are the evaluations made and the results.

1. John Oliver from Harvard tested their set of Far Detector electronics in the new crate with the Wiener power supply and saw the following.

   1.1. Their measure of performance is the "pedestal width" of the front end board as measured by the VARC. This increased by about 3% which they do not consider significant. So they said that there is no noticeable decrease in performance with these supplies.

   1.2. They measured 7mv rms ripple at a few hundred kHz on the 3.3 volt line when loaded with 6A (a very light load). This seemed acceptable.

   Note: Harvard had the power supply for only a week in which time they made the measurements above. .John has expressed a desire to use the power supply over a longer period.

The power supply prototype was shipped to Fermilab and the remainder of the test in this note were performed here.

2. Ripple on the VDC outputs was measured to be less than 14 mV with in a bandwidth of 20 MHz.

3. Conducted EMI coupled back onto the AC input power line was found to be larger than expected. Our equipment is not certified, but I would wager to say that the prototype supply would not meet the FCC class B specification as it is now. The 3.3V supply appears to be the source of most of this EMI.
4. Radiated EMI measured at the top of the power supply enclosure was found to be especially large. The largest portion of this noise appears to be generated by the supplies processor controlled mainframe which is in operation even when all of the VDC outputs are turned off. The radiated EMI from the surface of the power supply enclosure was, however, attenuated down into the range of a typical front-end electronics module by using a piece of sheet metal with 1/8" holes spaced on 3/16" centers to provide shielding between the supply and the EMI probe.

III. Conclusions and Recommendations

The good news is that EMI does not find its way out on the VDC outputs. The low output ripple specification appears to have been met in this prototype. Also if the radiated EMI is suspected to cause the electronics trouble we believe we could eliminate the problem by provide additional shielding. Perhaps also, there is something amiss with this prototype resulting in this high radiated EMI that can be discovered and remedied.

Manfred Plien from Wiener was here at Fermilab on October 26. At that time he was able to view the spectrum analyzer trace of the conducted noise from the prototype. He commented that the conducted EMI could be reduced with a different arrangement of the VDC output modules within the chassis. I suspect that there is also something else atypical with this prototype and would recommend taking the time to ask Wiener to take this prototype back for a short period to examine the supply and bring this supply within their specification for the product. This extra time to cycle the power supply back through Wiener needs to be balanced with the need for John Oliver to do further evaluation of the supply using his electronics as the benchmark and meeting the needed schedule for delivery of the production quantity of supplies.

It could be that we are sufficiently confident that the EMI measured will not be a problem for the Minos Far Detector electronics so that Harvard can be left with the prototype power supply for the full evaluation period available in the schedule. In this case we could proceed in evaluating the power supply for the Minos Near Detector.

IV. Description of the Conducted EMI Measurements

A Line Impedance Stabilization Network (LISN) was used in measuring the conducted noise from the Wiener prototype power supply and a ASTEC #VS3-D2-G33-00 +5VDC power supply. The ASTEC was a supply we had on hand that we could load to the same current as the Wiener and make a comparison. The ASTEC is rated for 240 Amps at 5VDC and 40 Amps at +/- 12VDC. Note that the LISN is rated for 120 VAC, single phase up to 10 Amps. Though the Wiener power supply is expected to use 220 VAC single phase, the output of the supply was not loaded beyond 50% of its rating and should therefore meet specifications with a 120 VAC input. The LISN is used to filter AC power to the Equipment Under Test (EUT) and then via a highpass filter pick off the conducted noise the device would be contributing to the power distribution system. The LISN output was monitored with a spectrum analyzer in the band from 9KHz to 30MHz. The schematic for the LISN is shown in Figure IV.1. Figure IV.2 shows the typical equipment setup for these tests.

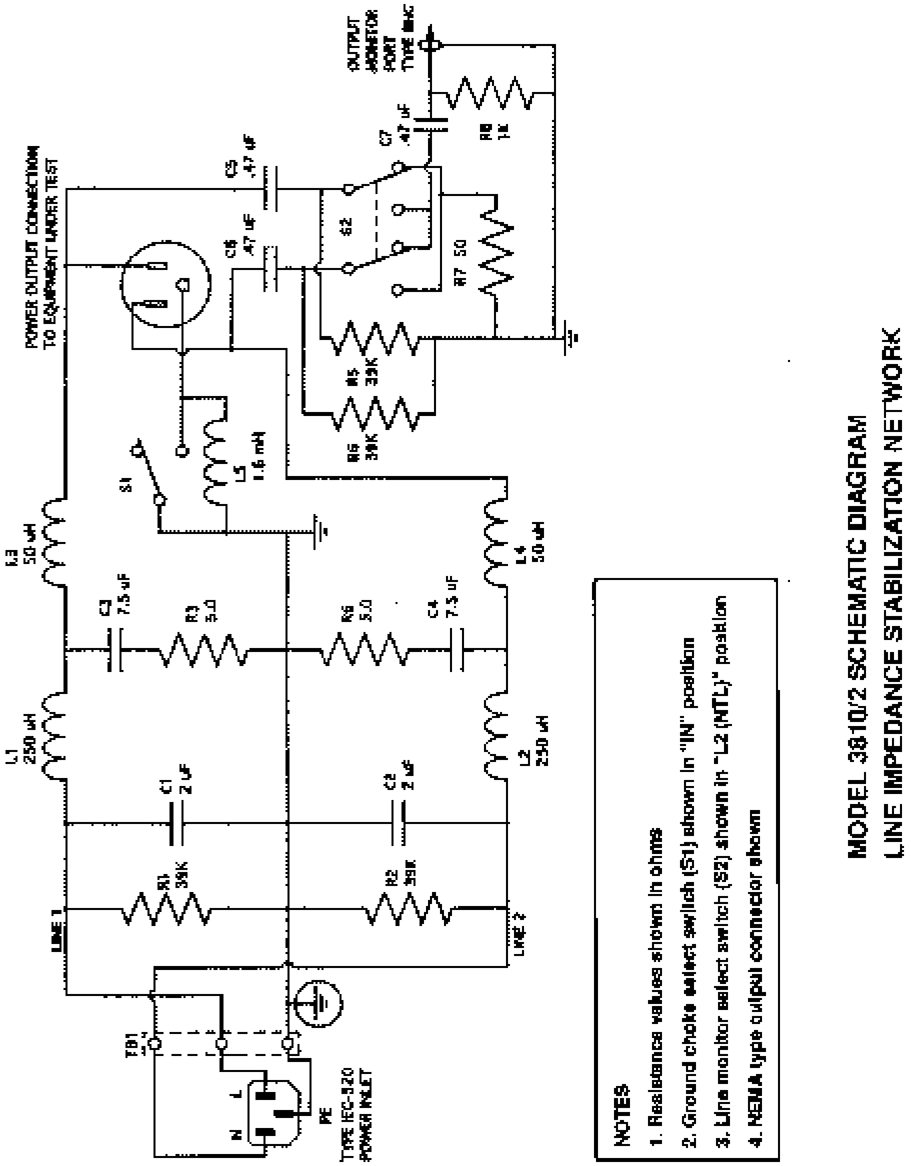


Figure IV.1. Schematic of the LISN Model 3810/2 (EMCO, Austin, Texas).

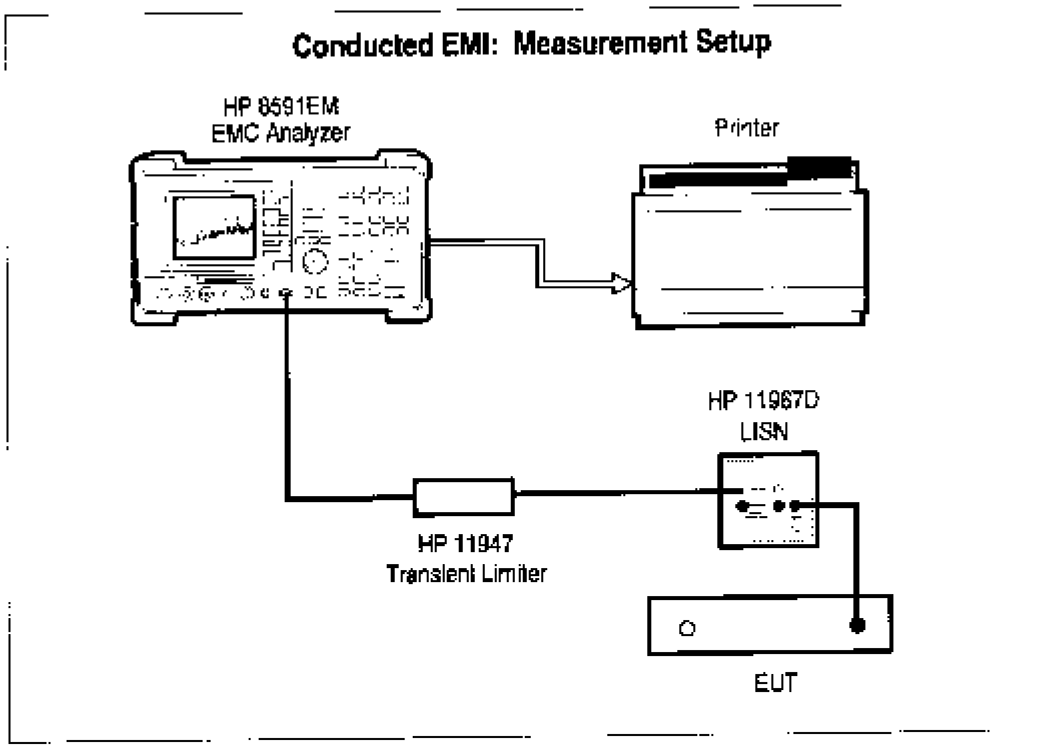


Figure IV.2. Setup for the conducted EMI tests.

Here is a summary of the spectrum analyzer screen shots given below.

Figure IV.3 Baseline for the ASTEC supply conducted EMI measurement (reg 9).

Figure IV.4 Measured EMI from ASTEC with 47 Amp load on the +5VDC (reg 12).

Figure IV.5 Baseline for the Wiener supply conducted EMI measurement (reg 13).

Figure IV.6 AC power applied to the Wiener supply, but VDC outputs off (reg 14).

Figure IV.7 Wiener supply +5VDC output with 47 Amp load (reg 15)

Figure IV.8 Wiener supply, 47 Amps on +5VDC and 29 Amps on +3.3VDC (reg 16).

The limit lines shown on the plot represent those for the specification EN55022 Class B Conducted EMI limits.

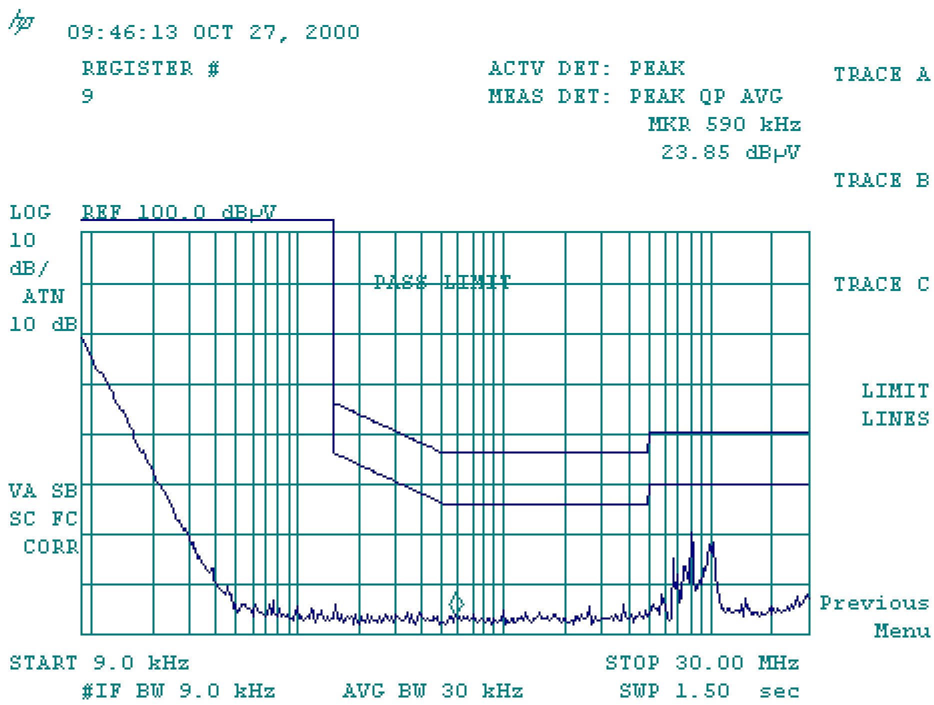


Figure IV.3 Baseline for the ASTEC supply conducted EMI measurement (reg 9).

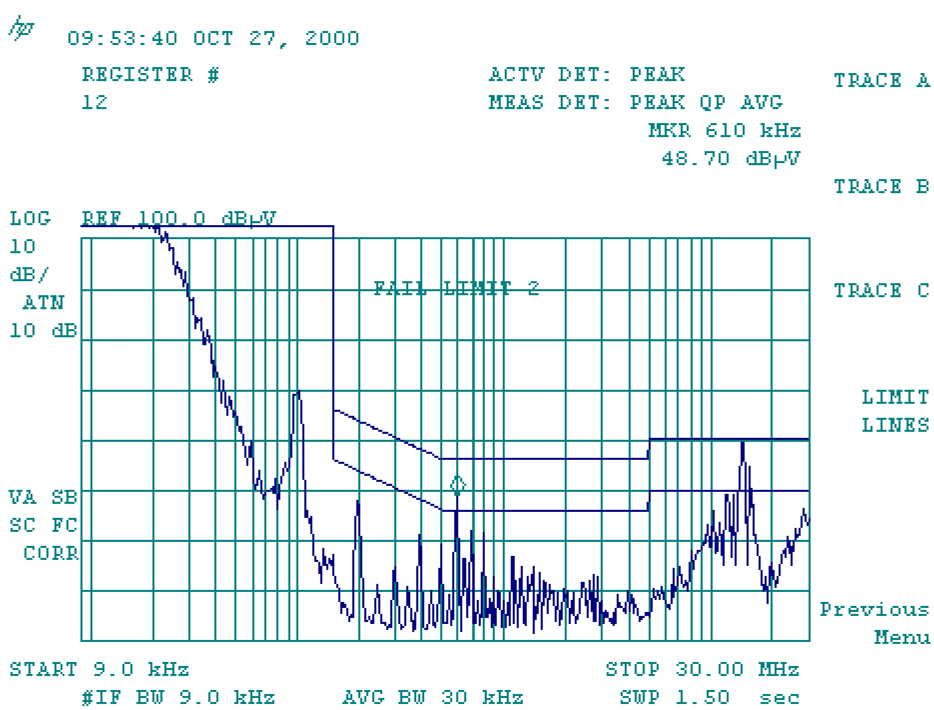


Figure IV.4 Measured EMI from ASTEC with 47 Amp load on the +5VDC (reg 12).

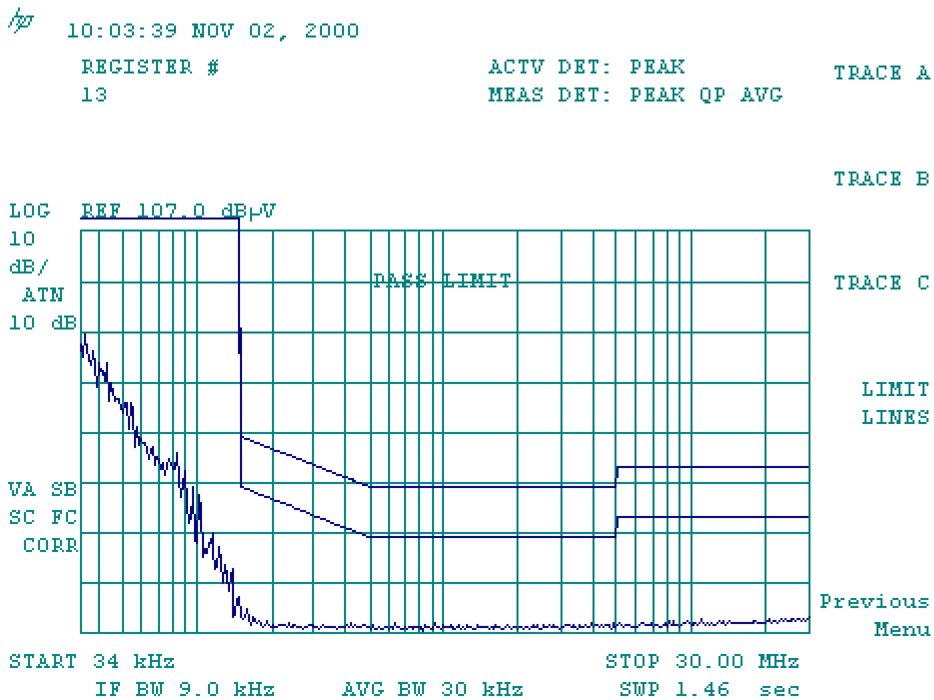


Figure IV.5 Baseline for the Wiener supply conducted EMI measurement (reg 13).

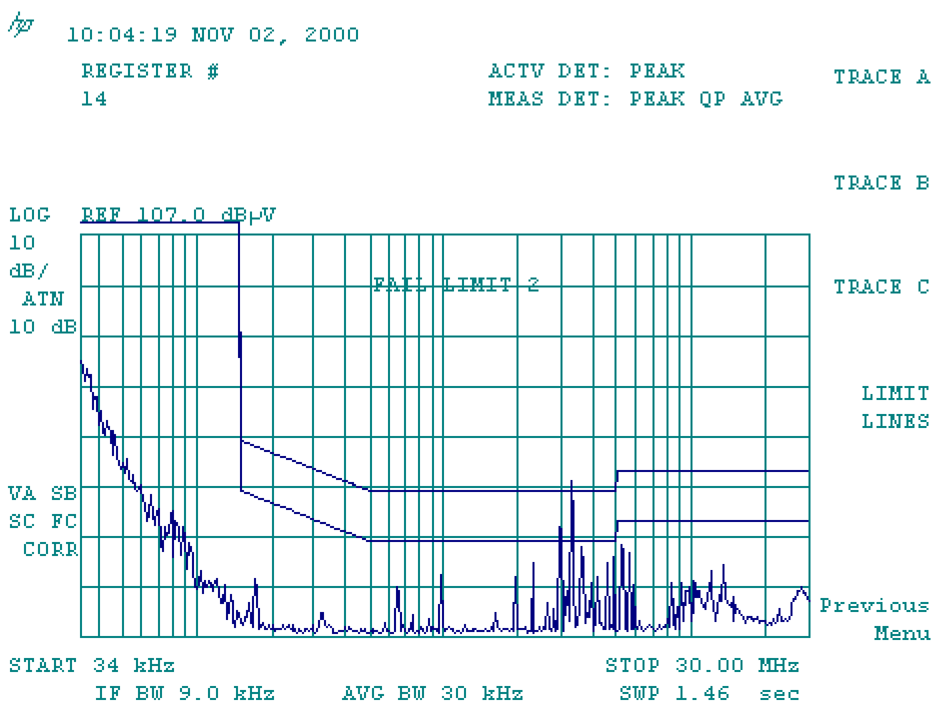


Figure IV.6 AC power applied to the Wiener supply, but VDC outputs off (reg 14).

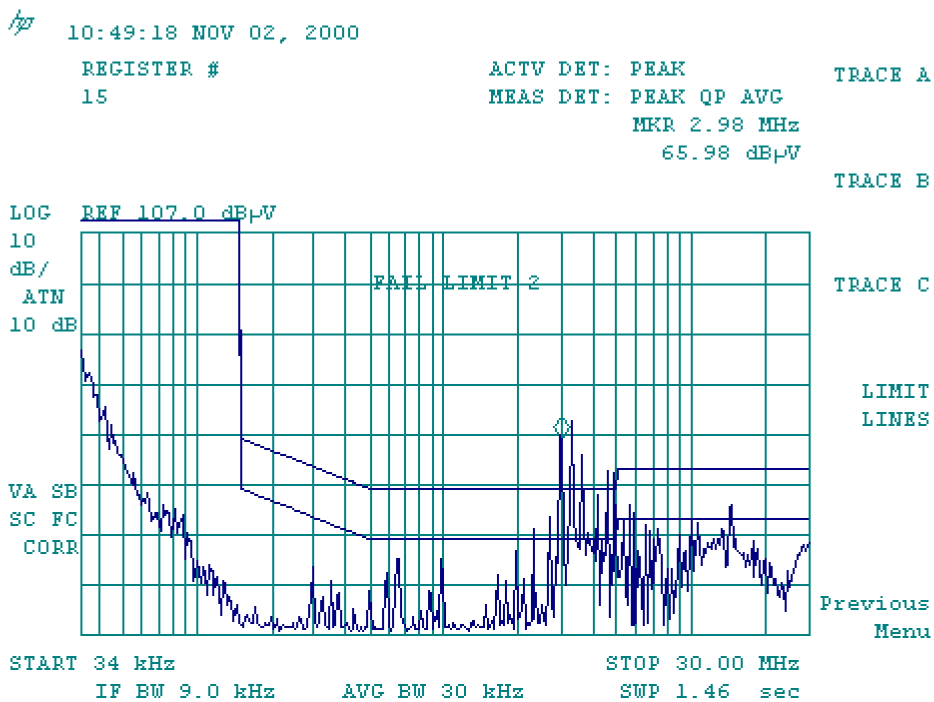


Figure IV.7 Wiener supply +5VDC output with 47 Amp load (reg 15)

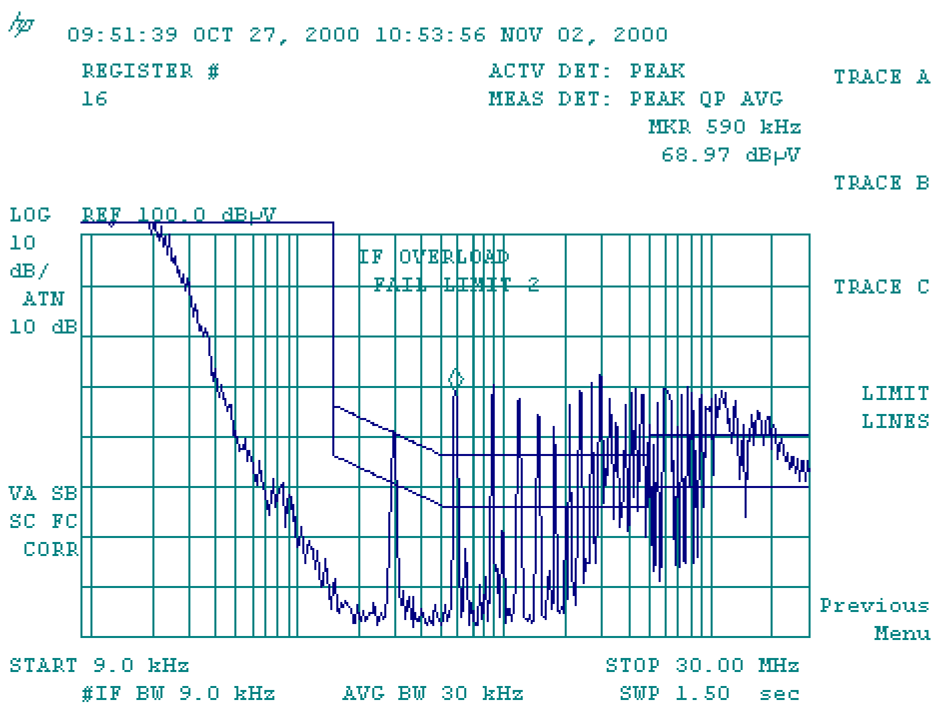
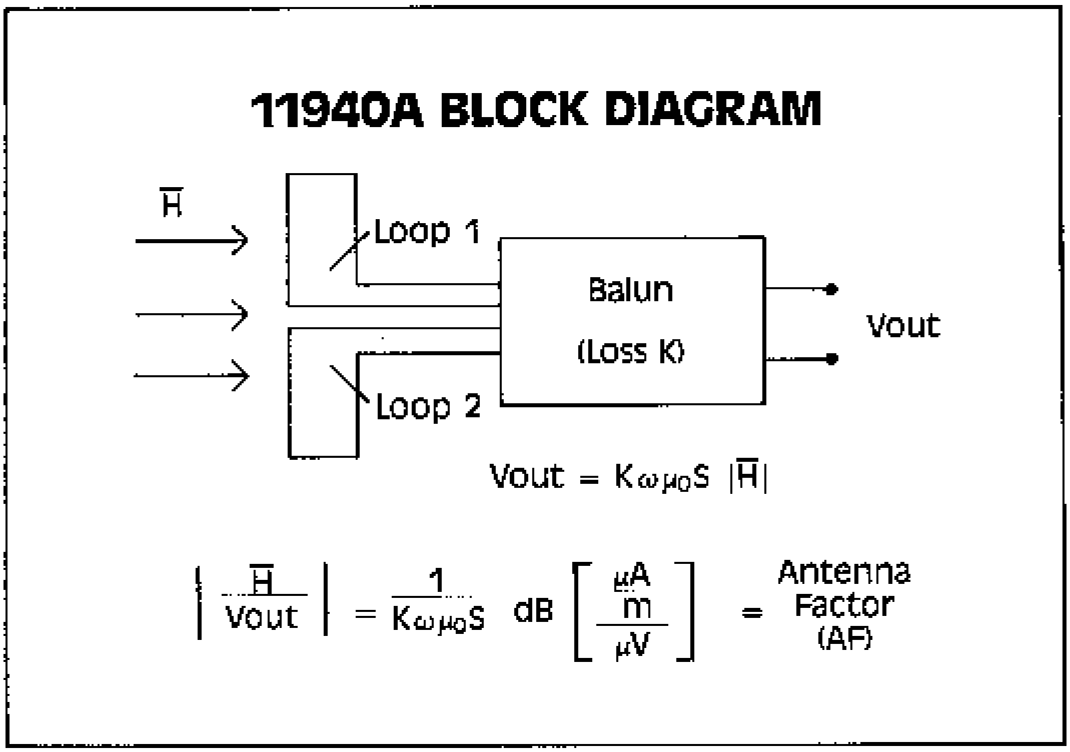


Figure IV.8 Wiener supply, 47 Amps on +5VDC and 29 Amps on +3.3VDC (reg 16).

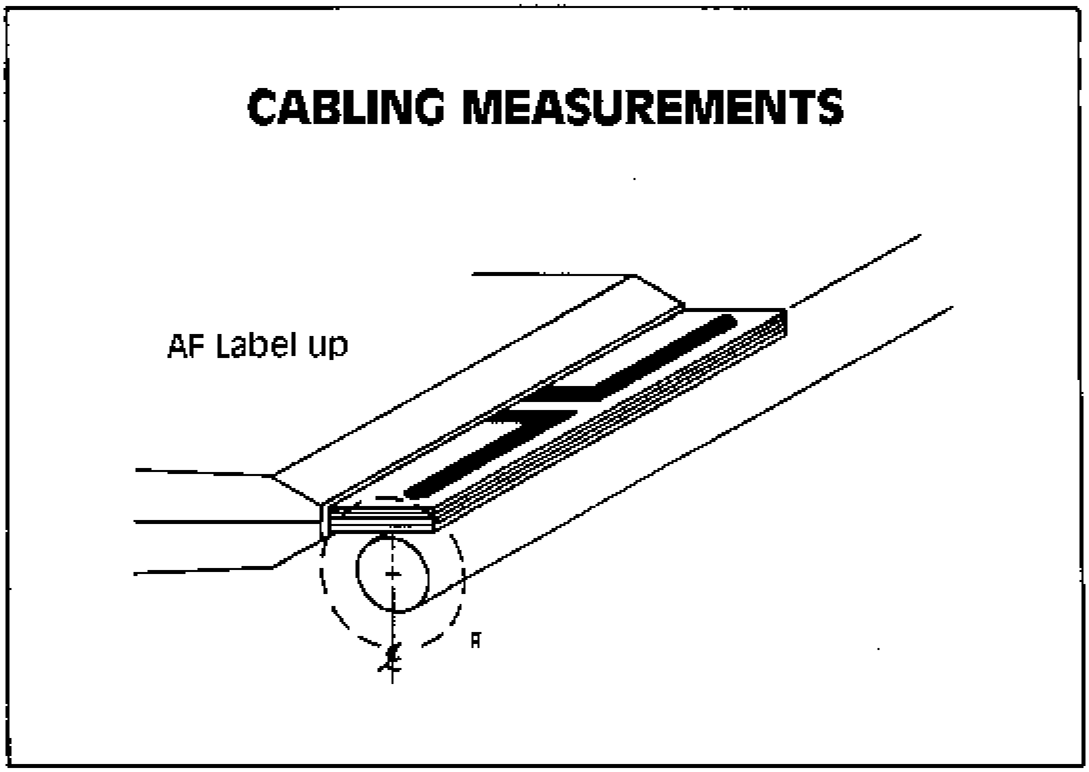
V. Description of the Radiated EMI Measurements

The HP11940 close field probe was used as the antenna for detecting radiated noise in the vicinity of the power supply enclosure. The HP11940 close field probe is a broadband magnetic field sensor designed for EMI troubleshooting the band between 150 KHz and 30 MHz. Figure V.1. gives a block diagram of the probe. Figure V.2. illustrates the manner in which the probe is used to measure radiation from a cable. In a similar way, we used the probe to measure EMI at openings in the power supply enclosure.



The 11940A consists of two single turn loops feeding a balun structure. The balun structure improves the performance of the probe but introduces additional losses. These losses are taken into account in the relationship between the CW magnetic field intensity at the probe tip and the output voltage. This relationship is called the antenna factor (AF) of the probe.

Figure V.1. Block diagram of the HP11940 close field probe.



Linearly-oriented common-mode current distributions that exist on single- or multi-conductor cables have strong circumferentially-oriented magnetic field components. The loops of the 11940A should be oriented in the r-z plane to measure this field. These structures should be measured with the antenna factor label facing away from the cable under test. Slight variations in output voltage (1 to 2 dB) will be observed between the two probe orientations when measuring fields with a very high spatial gradient, due to circuitry differences on each side of the 11940A. Caution should be exercised when analyzing the measurements of the close field of structures that carry both differential- and common-mode currents. The field very near the radiator contains components of both types of current: the field of the differential mode is not completely cancelled.

Figure V.2 Illustration of how the probe can be used.

Below is a summary of the spectrum analyzer screen shots that follow. In each case the spectrum analyzer was setup to retain the maximum field measured at each frequency in the band. With this Max Hold feature enabled the surface of the electronic circuits and power supplies were scanned using various orientations of the probe. In Figure V.4 we see the results of laying a piece of sheet metal with 1/8" holes on 3/8" centers on the top of the Wiener supply and then probing the surface of the sheet metal. Additional electronic devices were scanned to provide a reference to the amount of radiated EMI detected.

Figure V.3. Top surface of the Wiener prototype power supply.

Figure V.4. Top surface of the Wiener prototype with added shielding.

Figure V.5. Radiated noise from an MVME162 crate processor board.

Figure V.6. Radiated noise from a CDF TestClock V4 board.

Figure V.7. Radiated noise from a CDF Shower Max Crate Controller board.

Figure V.8. Radiated noise from an ASTEC # VS3-D2-G33-00 power supply.

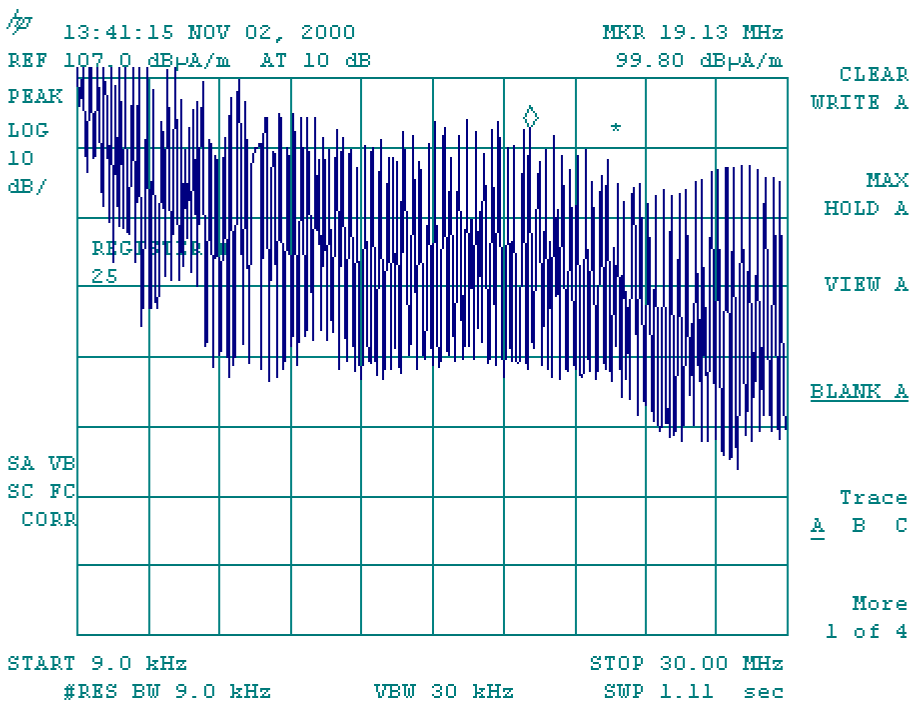


Figure V.3. Top surface of the Wiener prototype power supply.

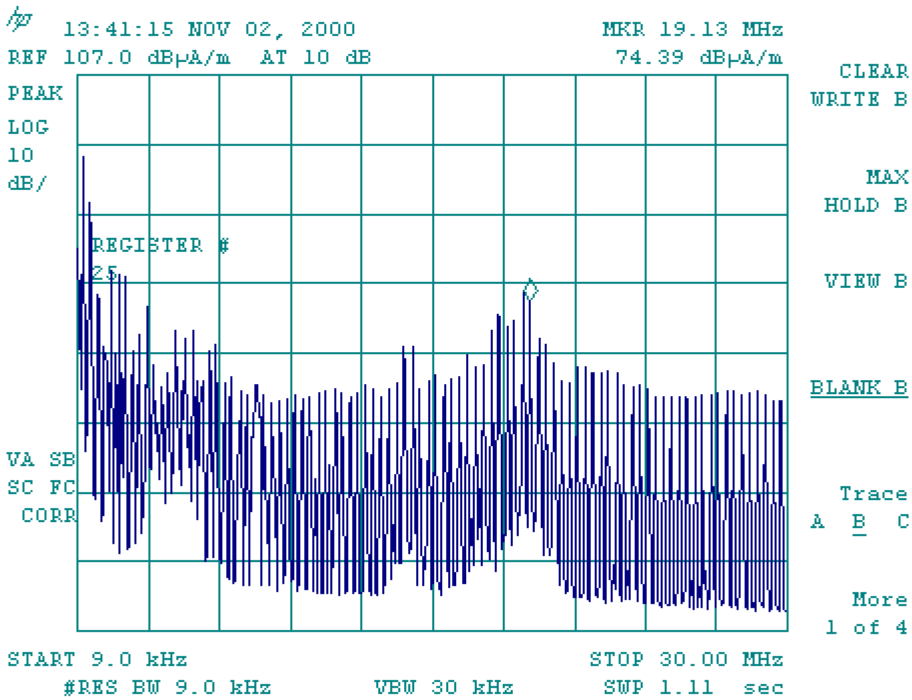


Figure V.4. Top surface of the Wiener prototype with added shielding.

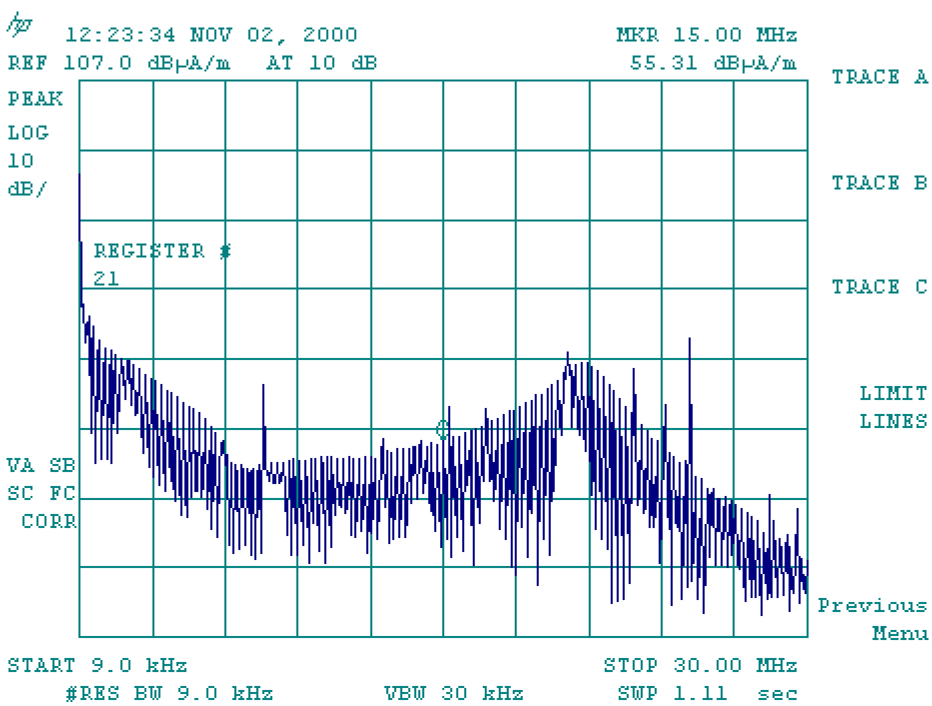


Figure V.5. Radiated noise from an MVME162 crate processor board.

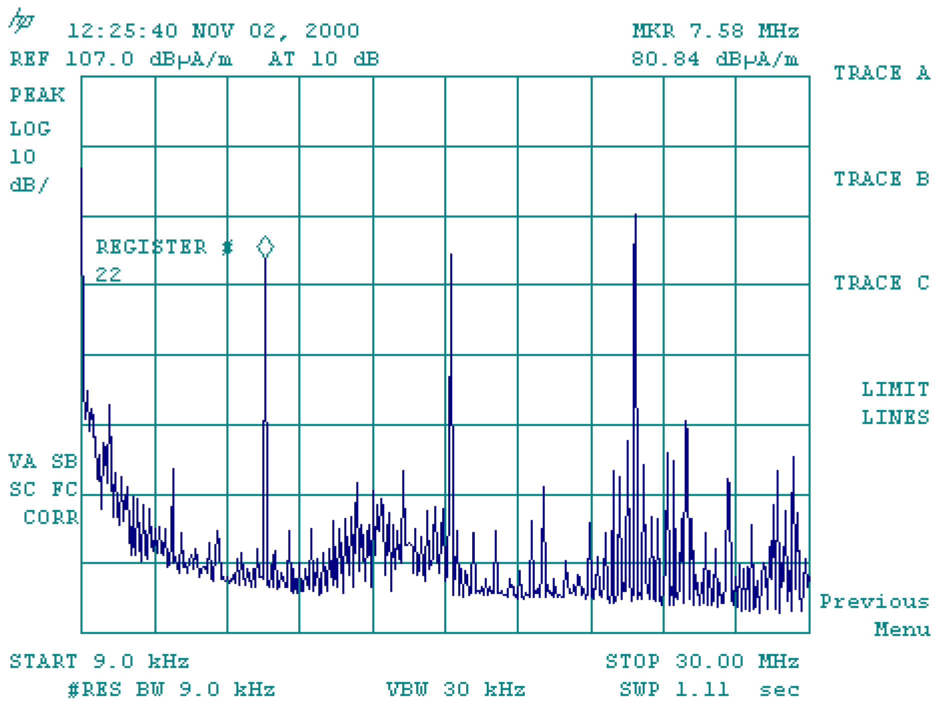


Figure V.6. Radiated noise from a CDF TestClock V4 board.

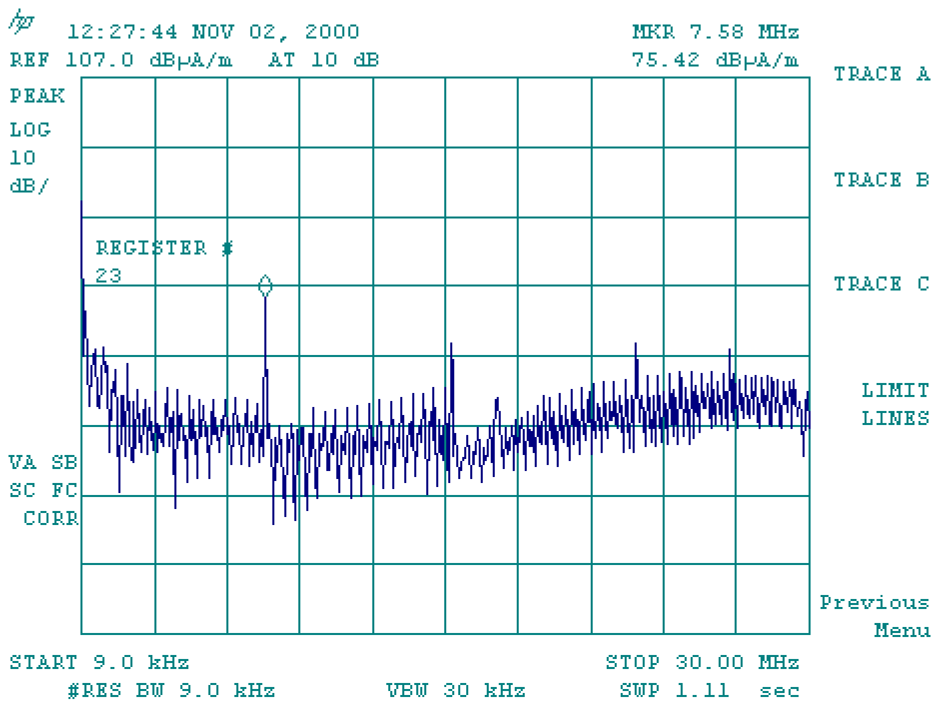


Figure V.7. Radiated noise from a CDF Shower Max Crate Controller board.

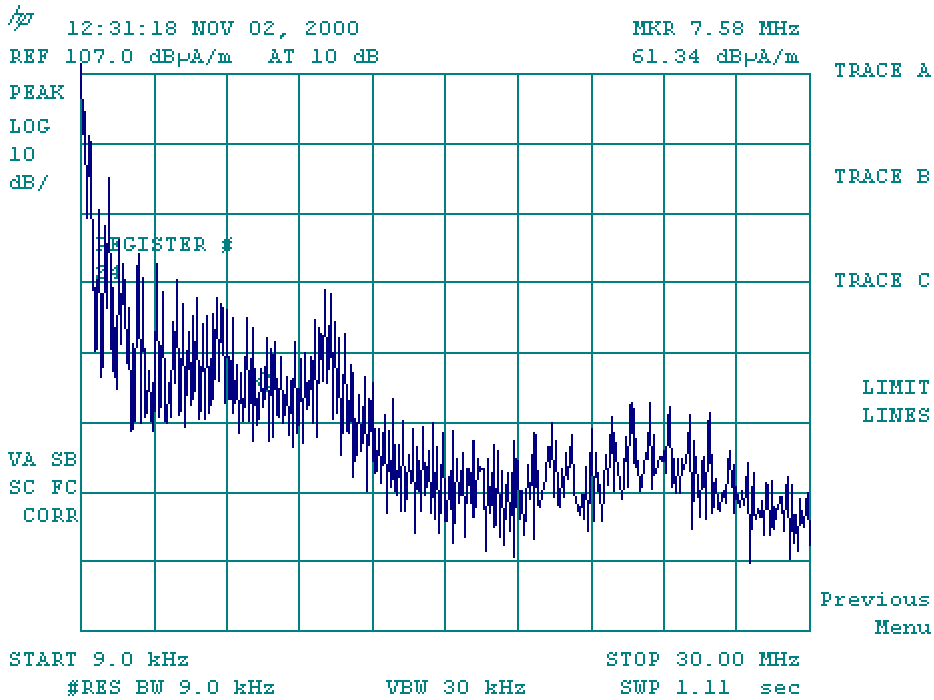


Figure V.8. Radiated noise from an ASTEC # VS3-D2-G33-00 power supply.